1505

INSTRUCTIONS AND APPLICATIONS

Deviation Bridge Type 1505

Adapted for the checking of resistors, capacitors and inductors, in industrial production and laboratories.

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ELECTRONIC MANUFACTURERS' REPRESENTATIVES
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Deviation Bridge

Type 1505

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Description.

General.

The Deviation Bridge is a measuring bridge for testing resistors, capacitors and inductors.

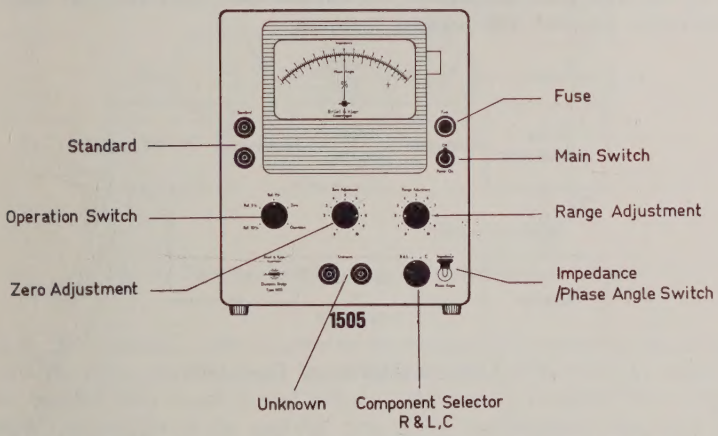


Fig. 1. Drawing of the Deviation Bridge Type 1505.

It consists of a Wheatstone Bridge with two fixed resistors and two sets of input terminals for connection of an external standard and the unknown component. The bridge is operated from a built-in generator. The diagonal voltage is, via a two-stage amplifier, fed to a phase-sensitive demodulator, the output voltage of which is measured on a moving coil instrument with a big, interchangeable scale. The scale-reading is the positive and negative impedance deviation in per cent and the positive and negative phase angle deviation in radians between the standard and the unknown component.

Four calibrated, and two blanco scales for special calibration purposes are supplied with the Bridge.

Oscillator and Bridge Section.

The oscillator, which is of the Hartley type, operates at a frequency of 10 kc/s. The output voltage is fed to an output amplifier via a resistor or a R-C network. The selection is made by means of the switch marked "Impedance", "Phase Angle". When switched in, the R-C network introduces a 90° phase shift of the output signal.

Via a potentiometer marked "Range Adjustment" the signal is fed to the output amplifier consisting of a pentode. In order to avoid any phase shift in being produced in this stage, the load must be true resistive. By parallelling the output transformer with a capacitor and making the transformer tuneable by introducing an adjustable air-space in the iron core, the anode circuit may be adjusted to the bridge frequency, whereby the said condition is obtained. This is only true when the secondary load of the transformer is resistive. By a capacitive load (i.e. when measurements are carried out on capacitors) the small extra phase shift causes an error which is corrected for by the table given on page 11. To stabilize the output amplifier this is, furthermore, supplied with negative feedback.

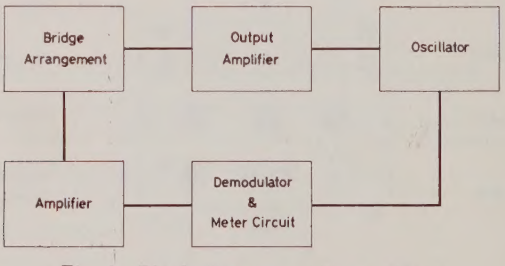


Fig. 2. Block diagram of Type 1505.

The two fixed resistors incorporated in the Wheatstone Bridge are wire-wound resistors of 100 Ω, the mutual point of which is grounded. The two other arms of the bridge are fed to two pairs of terminals marked "Standard" and "Unknown". None of the apparatus terminals is connected to chassis. The upper of the left terminals and the right terminal at the bottom are connected to chassis through resistances of about 100 Ω, having an AC potential of maximum 2 volts with respect to chassis. The other two terminals, marked in white, are mutually connected and led to the input circuit of the amplifier. The bridge arrangement involves, furthermore, a switch marked "R & L", "C", the purpose of which is to interchange the standard and the unknown component. This is to permit direct reading in % deviation of capacity (and not of impedance), and is necessary because the impedance of a capacitor is inversly proportional to the capacity.

Amplifier and Demodulator Section.

Whenever a difference in magnitude or phase angle is present between the standard and the unknown component, a diagonal voltage occures in the bridge arrangement. This voltage is fed directly to the input of a two stage resistance coupled amplifier, which is supplied with negative feedback to obtain a stable operation and a high input impedance. (When measuring too high impedance values, the input impedance of the amplifier will load the bridge, and consequently cause erroneous measurements. See correction curves on p. 21). The output of the amplifier is connected to a demodulation circuit which makes the instrument insensitive to hum and noise voltages to a certain degree, because the demodulator preferably responds to signals of the same frequency as that of the oscillator. Furthermore, positive and negative deflections are obtained for positive and negative deviations from the standard, respectively.

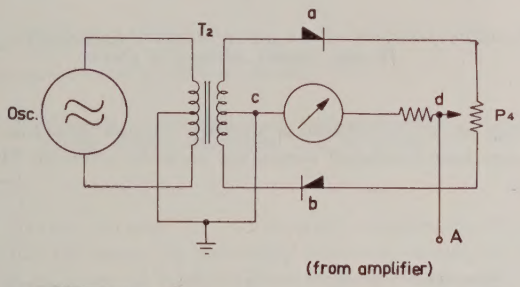


Fig. 3. Principle diagram of the demodulator circuit.

In fig. 3 is shown a basic diagram of the demodulator circuit. It can be seen from the figure that a part of the oscillator voltage is rectified by means of the rectifier cells a and b, and that by adjusting P_4 (marked "Zero Adjustment") a position of the movable arm of the potentiometer can be found, for which no current will flow through the meter, when no signal is fed to A.

Whenever a diagonal voltage occurs in the bridge arrangement, the corresponding amplified signal, with no additional phase shift, is present at A. If this voltage is in phase with the voltage E_T across the secondary of the transformer T_2 as indicated in figure 4 and the rectifier cells a and b are open, only a small current will pass through the meter due to the shunting effect of the rectifiers.

When the cells are blocked the current will flow from c to d, having a magnitude which is much greater than when the cells are open. A DC component of the output voltage from the amplifier will thus be present across the meter, causing this to deflect.

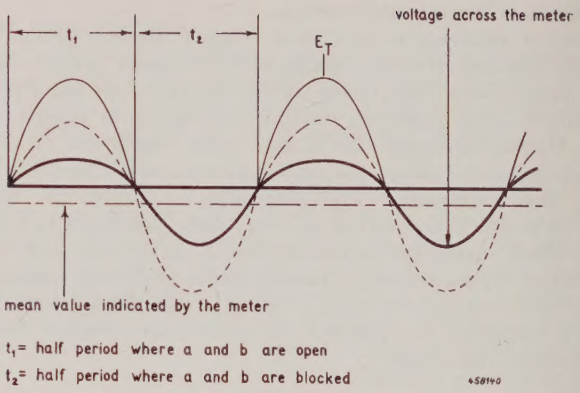

voltage across the meter
t_1
t_2
E_T
mean value indicated by the meter
t_1= half period where a and b are open
t_2= half period where a and b are blocked
+58140

Fig. 4. Operating principle of the phase sensitive demodulator. Oscillator and bridge output voltage in phase.

If the voltage at A is in antiphase with the voltage E_T across T_2 the sign of the DC component developed across the meter is reversed. This can be seen from fig. 5.

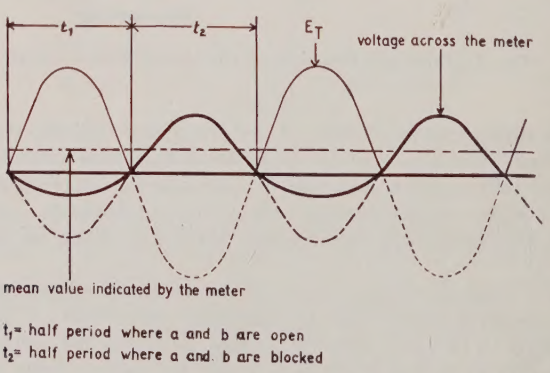

t_1
t_2
E_T
voltage across the meter
mean value indicated by the meter
t_1= half period where a and b are open
t_2= half period where a and b are blocked

Fig. 5. Operating principle of the phase sensitive demodulator. Oscillator and bridge output voltage in anti-phase.

With the output voltage from the amplifier 90° out of phase, relative to the voltage E_T, the voltage developed across the meter will be as indicated in

fig. 6. No DC component is then present, and the deflection on the meter will be zero.

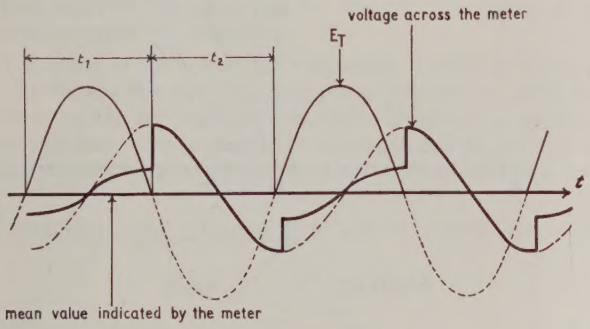

voltage across the meter
E_T
t_1
t_2
t
mean value indicated by the meter
t_1= half period where a and b are open
t_2= half period where a and b are blocked

Fig. 6. Operating principle of the phase sensitive demodulator. Oscillator and bridge output voltage 90° out of phase.

Consequently only the in-phase (or in-antiphase) component of the voltage will be indicated by the meter. By measuring both components, the magnitude as well as the phase angle of the diagonal voltage are determined. With the switch marked "Impedance/Phase Angle" in position "Impedance", the in-phase (or in-antiphase) component is measured, and with the switch in position "Phase Angle" the 90° out of phase component is indicated. In fig. 7 a vector diagram of the voltages appearing in the Wheatstone Bridge arrangement during measurements is shown.

The vectors AB and BC represent the voltages across the two fixed resistors, respectively, the vectors AD and DC the voltages across the "standard" and the "unknown" impedances, respectively, and the vector BD the voltage applied to the amplifier.

When impedance measurements are taken only the voltage represented by the vector BD_1 is indicated by the meter.

For phase-angle measurements the meter indication will be proportional to the voltage BD_2.

It is seen from the diagram that the point D might move along a line drawn through the points D—D_1 without influencing the magnitude of the vector BD_1.

Analogously the magnitude of the vector BD_2 will not be influenced if the point D moves along a line drawn through the points D—D_2.

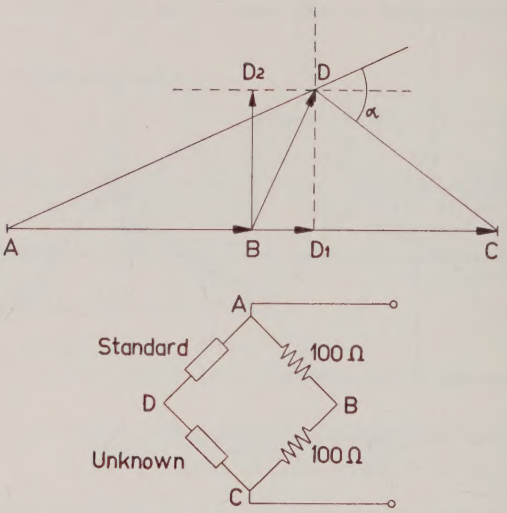


Fig. 7. Vector diagram of bridge voltages.

As the difference in phase angle between the "standard" and the "unknown" is α (see fig. 7) this means that:

1. When the phase angle of the "unknown" is very much different from the phase angle of the "standard" the measurement of impedance deviation is inaccurate.
2. When the impedance of the "unknown" is very much different from the impedance of the "standard" the measurement of phase angle deviation will be inaccurate.

The maximum inaccuracy will be present when both phase angle and impedance measurements show maximum deviation between "standard" and "unknown".

Meter Section.

As previously mentioned, different dials can be inserted in the large square type indicating meter.

The four calibrated scales, supplied with the instrument cover the following ranges of deviation measurements:

Impedance Deviation	*Phase Angle Deviation (tan δ)*	*Range Adjustment*
− 1.5 % to + 1.6 %	− 1.5 to + 1.5 × 10^{-2}	1 %
− 7 % to + 8 %	− 7 to + 7 × 10^{-2}	5 %
−25 % to + 35 %	−30 to + 30 × 10^{-2}	20 %
−50 % to + 100 %	−80 to + 80 × 10^{-2}	20 %

The moving coil instrument is slightly under-critically damped to secure maximum speed, and is perfectly protected against overload.
To be able to calibrate the apparatus for the different ranges in a quick way, reference voltages are provided.

When the 1 % range is to be used the "Operation Switch" is set to position "Ref. 1 %". By turning the knob marked "Range Adjustment" until the meter pointer deflects to the red mark on the scale, a voltage is applied to the input of the amplifier, with a magnitude corresponding to the one obtained when the impedance deviation between the standard and unknown impedance is 1 %.

Reference voltages for the 5 %, the 20 % and the 100 % ranges are also available.

Power Supply.

The European model is intended for use with 115, 127, 150, 220 or 240 volts AC, 40—400 c/s. Switching to the different line voltages is made by means of a screwdriver through a hole in the back plate. A pilot disc indicates the line voltage to be connected. The American model is designed for 115 volts, 60 c/s. The power consumption for both models is about 40 watts. The plate voltage to the oscillator is stabilized by a neon tube. A variation of 10 % in the power supply voltage will influence the meter deflection by less than 3 %, the zero point being independent of the line voltage.

Operation.

General Remarks.

During measurements it is advantageous to ground the apparatus.

The standard and the objects to be measured should be placed together with the bridge on a grounded metal plate.

If the object to be tested is grounded, the grounded pole should be connected to the right "Unknown" terminal, and the grounding of the cabinet be omitted. The capacity of the apparatus to ground is then connected across one of the built-in ratio resistors and should consequently be kept as low as possible.

When high impedances are being measured (large resistors and inductances, and small capacitors, respectively) the connections to the bridge should be kept short to reduce the influence of wiring capacity.

For measurements on small impedances the effect of the wiring inductances should be taken into account.

Furthermore, no extra capacity must be introduced between chassis and the two terminals marked in white.

Operation Procedure.

1. Make sure that the Deviation Bridge is adjusted to the correct mains voltage. If not turn the pilot disc on the rear panel of the instrument to the desired voltage (115 — 127 — 150 — 220 or 240 volt).
2. Connect the power cable to the mains and place the toggle switch marked "Power" in position "On". The light on the meter comes on immediately.
3. Allow a few minutes warm-up time.
4. Set the switch marked "Impedance/Phase Angle" in position "Impedance".
5. Place the meter scale corresponding to the desired measuring range 1 %, 5 %, 20 % or 100 %) in the meter frame. (The scale is removed from the frame by pulling to the right.)
6. Turn the "Operation Switch" (knob to the left) to "Zero". By means of the knob marked "Zero Adjust" the meter pointer is set to O.
7. Connect the standard component to the terminals marked "Standard" and the component to be checked to the terminals "Unknown".
8. Set the "Operation Switch" to the desired Ref. value ("Ref. 1 %", "Ref. 5 %" or "Ref. 20 %". For the 100 % range the 20 % reference is used). Turn the knob marked "Range Adjustment" until the meter pointer is on the red mark on the scale.

Range		Introduced Error	Capacity to be tested
20 %	Impedance measurement	0.05 × b	up to 0.1 μF
		0.05 × b	at 0.5 μF
		0.14 × b	at 1 μF
	Phase angle measurement	0.16 × a	up to 0.1 μF
		0.13 × a	at 0.5 μF
		0.05 × a	at 1 μF
5 %	Impedance measurement	0.03 × b	up to 0.1 μF
		0.06 × b	at 0.5 μF
		0.12 × b	at 1 μF
	Phase angle measurement	0.05 × a	up to 0.1 μF
		0.06 × a	at 0.5 μF
		0.08 × a	at 1 μF
1 %	Impedance measurement	0.07 × b	up to 0.1 μF
		0.10 × b	at 0.5 μF
		0.16 × b	at 1 μF
	Phase angle measurement	0.04 × a	up to 0.1 μF
		0.07 × a	at 0.5 μF
		0.12 × a	at 1 μF

Table 1. The extra inaccuracy which is introduced when measurements are carried out on capacitors. With an impedance deviation reading of a % and a phase angle deviation reading of b % the inaccuracy on the 3 different % ranges are directly found.

Note:
When measuring high impedances, the values obtained from the adjustment curves, shown on p. 21, should be used for the range adjustments, instead of the red mark on the scale. The curves given for the 20 % range is applicable for the 100 % range as well.

9. Turn the "Component Selector" to the correct position (for resistors and inductances to position "R & L" and for capacitors in position "C"). For the influence of capacitive loading see table 1.
10. Turn the "Operation Switch" to position "Operation" and the instrument is ready for use.
11. For *phase angle measurements* set the switch marked "Impedance", "Phase Angle" in position "Phase Angle". It is locked in this position by pushing it downwards and to the left.

Note:
To avoid overloading of the amplifier a check should be made that the meter deflection is kept within full scale deflection both with the press button switch in position "Impedance", and in position "Phase Angle".

12. The components to be tested are now successively connected to the terminals marked "Unknown" and the meter deflection will give the deviation from the Standard directly in %.

Deflection to the right means positive deviation (unknown bigger than Standard), and deflection to the left negative deviation (unknown smaller than Standard).

Accessories.

Test Jig Type 3902.

The Test Jig Type 3902 is a design to be used in connection with the Deviation Bridge for rapid production control of resistors, capacitors, and inductances. It consists of a wooden board on which the Deviation Bridge should be placed. On the board in front of the instrument are placed two posts designed with spring loaded contacts. The opening of the contacts is controlled by means of a lever, and the contacts can be directly connected to the terminals marked "Unknown". The lever is intended to be operated by

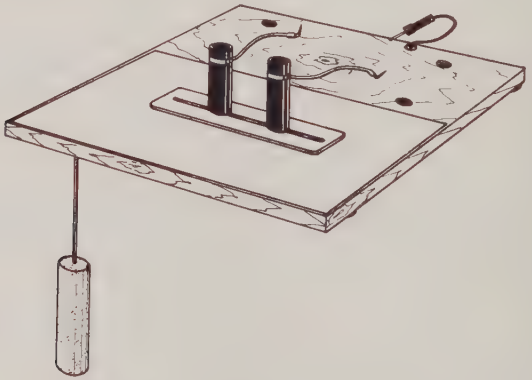


Fig. 8. Drawing of the Test Jig Type 3902.

means of the operators left knee. That part of the wooden board which is in front of the instrument is, furthermore, supplied with a steel plate. This may be connected to the instrument cover or to ground. The distance between the posts is adjustable to any spacing between 0 and 14 cm (5½ inch.). The measurements are carried out by engaging the lever for operating the contacts, placing the component to be measured between the two posts, and releasing the lever. The instrument then immediately shows the deviation from the standard-component employed.

Applications.

Laboratority Measurements of Resistors and Capacitors.
In laboratories where resistors and capacitors are frequently measured, it will be a practical advantage to set up a couple of measuring bridges of type 1505 permanently connected to the resistor and capacitor standard, as indicated in fig. 9.

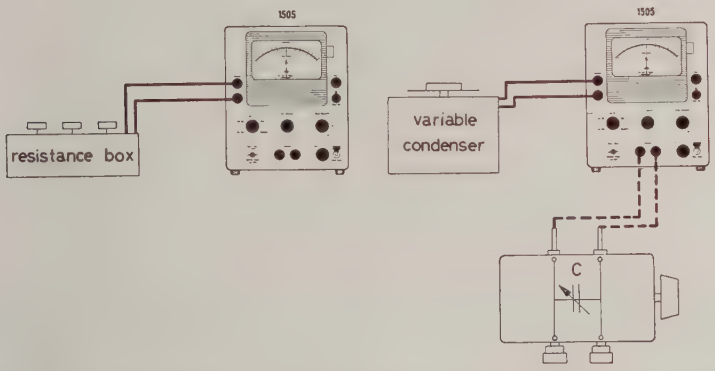


Fig. 9. Resistance box and variable capacitor connected to Deviation Bridge Type 1505.

Resistors are measured on 1505; the "Unknown" being connected to the Bridge, and the standard resistor being varied until the bridge is balanced. The unknown resistance can then be immediately found by reading off the value on the resistance box. This form of resistance measurement is much quicker in practice than adjusting a Wheatstone Bridge, because the meter of 1505 responds much quicker than the usual light-spot galvanometer.
Capacitors may also be measured on 1505 in exactly the same way. In order to compensate for the connections to the variable capacitor and its minimum capacity, the unknown capacitor should be connected via a small extra measuring box, containing a balancing capacity. In this way, a quick and very exact measurement of small capacitors can be carried out.

Checking of Coils for Short-Circuit Turns.

For checking coils in transformers, chokes, inductances etc., a set-up as indicated in fig. 10 is very useful. Two identical measuring coils with long iron cores are balanced on the bridge, and the coil under test is then placed over the end of one of the cores.

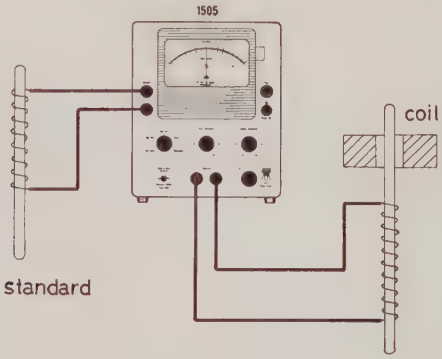


Fig. 10. Checking of coils.

If there is a short-circuit in the coil, the induction in the coil will react with the balanced coil, and deflect the meter pointer. In most cases a phase angle measurement will give the highest sensitivity.

Balance of Ganged Variable Capacitors.

For adjustment of coupled variable capacitors the set-up shown in fig. 11 will be practical. The two stators are connected to the upper left and lower right terminal of the bridge, respectively, while the rotors, which are as a rule

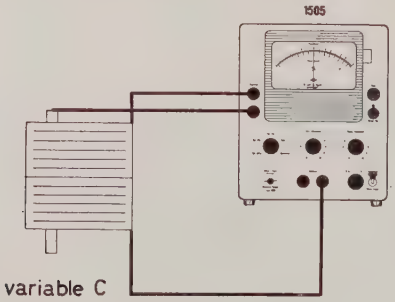


Fig. 11. Matching of variable capacitors.

connected together, are joined to one of the two remaining terminals. The balance expressed in % deviation may then be checked for all positions of the rotor.

Checking the Remanence of Permanent Magnets.

The remanence of the permanent magnets used for the adjustment of the horizontal linearity in TV sets may be checked by means of the Bridge Type 1505.

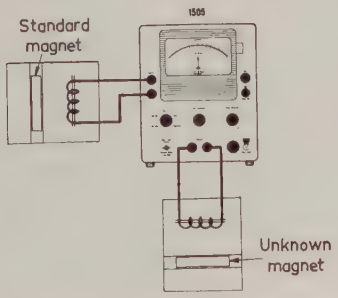


Fig. 12. Checking the remanence of permanent magnets for the adjustment of the horizontal linearity of TV receivers.

As shown in fig. 12 two identical coils are connected to the terminals of the Bridge. A magnet with the minimum remanence required for the TV set is placed besides the coil connected to the "Standard" terminals. The magnet to be checked is then placed besides the coil at the "Unknown" terminals in a relative position which equals that of the "Standard". A positive deflection on the meter means "go" because the remanence of the unknown is greater than that of the standard, and consequently, a negative deflection means "no go".

Direct-Reading Measurements of Capacitors.

The Deviation Bridge Type 1505 may be used as a direct-reading instrument for measuring capacitances. Two equal capacitors of exactly known capacitances are, as shown in fig. 13, connected across the "Standard" and "Unknown" terminals, one to each terminal. The capacitance to be found is measured as a per cent increase of the fixed known value. By choosing the fixed capacitors as pure powers of 10 the direct readings will be simplified. To make the adjustment easier it will be practical to have part of the capacitance on "Standard" placed as a small trimmer condenser.

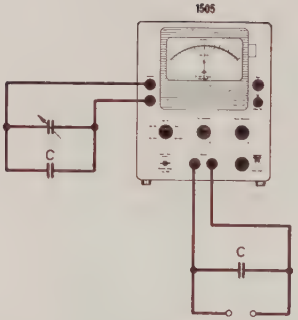


Fig. 13. Direct reading measurements of capacity values.

The procedure is then as usual: Set zero point and adjustment to reference, then switch to "Operation" and bring the pointer to zero in the middle of the scale by means of the adjustable part of the fixed capacitance. When the fixed capacitors are very small the reference adjustment should be done in accordance with the adjustment curves on p. 21. The following table shows ranges and adjustments to reference for various fixed standards chosen as powers of 10.

Fixed Capacitors	*Direct Reading Range*	*Adjustment to Reference %*
2 × 100 pF	0— 1.5 pF	1.12
	0— 8 pF	5.60
	0— 35 pF	22.7
2 × 1000 pF	0— 15 pF	1
	0— 80 pF	5
	0— 350 pF	20
2 × 0.01 μF	0— 150 pF	1
	0— 800 pF	5
	0— 3500 pF	20
2 × 0.1 μF	0— 1500 pF	1
	0— 8000 pF	5
	0—35000 pF	20
2 × 1 μF	0— 15 nF	1
	0— 80 nF	5
	0— 0.35 μF	20

Direct-Reading Measurements of Resistors.

In a similar way as for capacitances it is possible to use the Deviation Bridge as a direct-reading ohmmeter. As illustrated in fig. 14 two fixed resistors

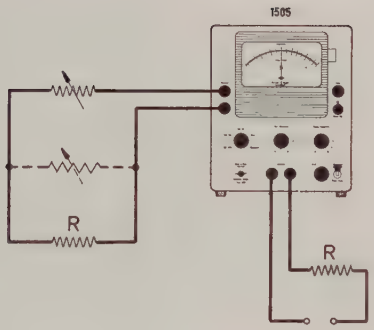


Fig. 14. Direct reading measurements of resistance values.

have to be used, but the resistance under test has to be connected in series with one of the fixed resistances. The small adjustable fraction of the other fixed R may be connected either in series or in parallel with R. If series connection is used, the adjustable R need only be a few per cent of the total value of the fixed resistance, while it has to be great compared to the total resistance if connected in parallel.

Fixed Resistance	*Direct Reading Range*	*Adjustment to Reference %*
2 × 10 Ω	0— o.15 Ω	1
	0— o.8 Ω	5
	0— 3.5 Ω	20
2 × 100 Ω	0— 1.5 Ω	1
	0— 8 Ω	5
	0— 35 Ω	20
2 × 1 kΩ	0— 15 Ω	1
	0— 80 Ω	5
	0—350 Ω	20
2 × 10 kΩ	0— o.15 kΩ	1
	0— o.8 kΩ	5
	0— 3.5 kΩ	20
2 × 100 kΩ	0— 1.5 kΩ	1
	0— 8 kΩ	5
	0— 35 kΩ	20
2 × 1 MΩ	0— 15 kΩ	1.54
	0— 80 kΩ	7.7
	0—350 kΩ	31.0

Direct-Reading Measurements of Inductances.

In a similar way as for capacitors, it is possible to use the Deviation Bridge as a direct-reading meter for inductances. As shown in fig. 15 two fixed

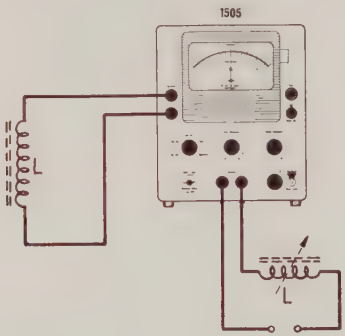


Fig. 15. Direct reading measurements of inductance values.

inductances are used, the inductance under test being connected in series with one of the fixed inductances.

Fixed Inductances	*Direct Reading Range*	*Adjustment to Reference %*
2 × 1 mH	0— 15 μH	1
	0— 80 μH	5
	0—350 μH	20
2 × 10 mH	0— 0.15 mH	1
	0— 0.8 mH	5
	0— 3.5 mH	20
2 × 100 mH	0— 1.5 mH	1
	0— 8 mH	5
	0— 35 mH	20
2 × 1 H	0— 15 mH	1
	0— 80 mH	5
	0—350 mH	20

Loss in Capacitors.

Most paper capacitors have a tan δ of approx. 1 %. The loss can easily be measured with the bridge on its $\pm$ 1.5 % range, provided that the standard has negligible loss and the capacity of the measuring object only deviates approx. 1 % from the capacity of the standard. If the paper capacitors are

only within the usual tolerance of $\pm 10\,\%$, the bridge must be set to impedance measurement, and the standard capacitors adjusted to give 0 reading on the meter. After that, the switch is depressed to phase angle measurements, and the tan δ is read off the scale. The loss of high-K ceramic capacitors will also be within the range of the bridge, whereas the loss in low-K ceramic and polystyrene capacitors is too small to be measured by that method.

Adjustment of Inductances.

An R.F.-coil is characterised by its inductance value, L, and quality factor

$$Q = \frac{1}{\tan \delta}$$

When manufacturing coils, the usual procedure is to design a "standard", and the coil produced by the manufacturing process shall then equal this "standard" to within certain limits.

A convenient method of checking and adjusting the coils, is by employing a Deviation Bridge Type 1505.

The "standard" coil should then be connected to the "Standard" terminals, and the coil to be checked to the "Unknown" terminals.

With the switch on "Impedance" the inductance is adjusted to give zero reading. The switch is then set to Phase Angle" and the Q of the coil adjusted to show 0 phase angle deviation.

Usually L and Q are, to a certain degree, dependent upon each other and it is therefore advisable to repeat the procedure when exact measurements are wanted.

Impedance of Magnetic Heads for Tape Recorders.

By means of the Deviation Bridge Type 1505 measurements of the impedance of heads for magnetic tape recorders are readily carried out. Before measurements begin attention must, however, be paid to the operational voltage of the head under test. As the bridge voltages for Type 1505 are approx. 3.5 volts, o.8 volts, and o.15 volts for the different measuring ranges (1 %, 5 %, and 20 %), it is sometimes necessary to use matching transformers as shown in fig. 16. The two transformers (T_1 and T_2) must be absolutely identical in order not to increase the deviation to be measured. For a reproduce head with the following data: current $I = 1.5$ mA and inductance $L = 7.5$ mH, the Bridge voltage may be calculated:

At 10 kc/s the voltage necessary is $V = I \times L\omega = 1.4 \times 7.5 \times 10^{-3} \times 2\pi \times 10^4 = 660$ mV. As the Bridge voltage for the 1 % range is $V_1 =$ approx. 3.5 volts, the half of which is impressed on the object under test, the transformer ratio n should be $n =$ approx. $\frac{3500}{2 \times 660} = 2.7$ in order to match the voltage. The impedance is then transformed from 7.5 mH into $7.5 \times n^2 = 55$ mH. As

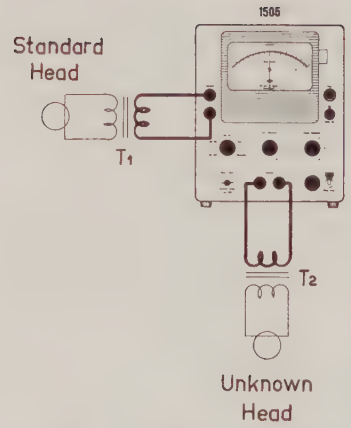


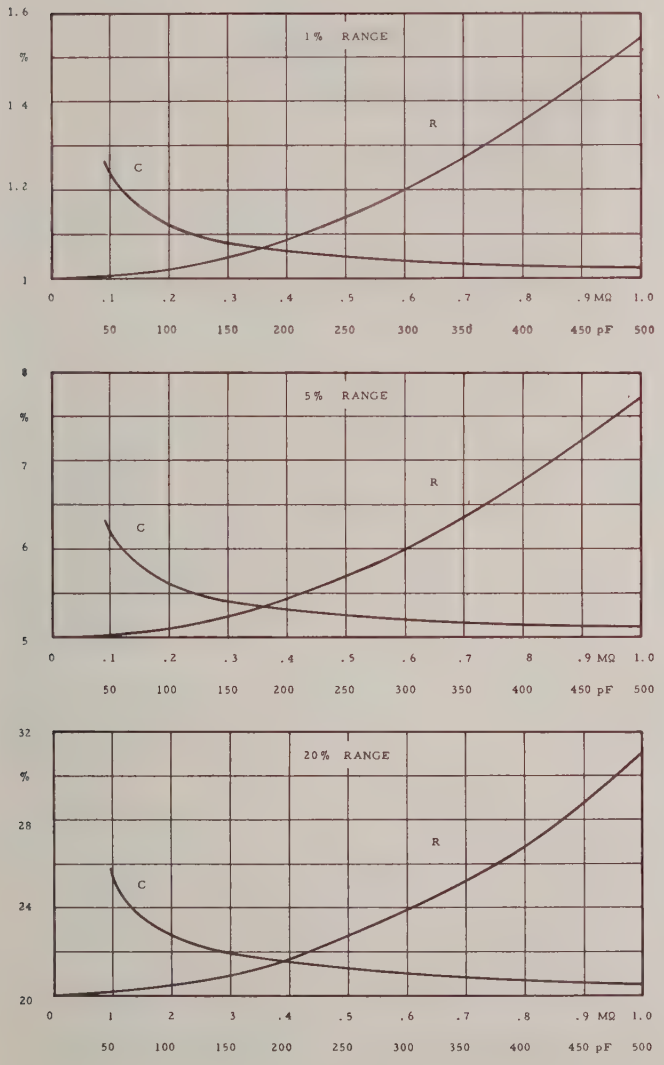
Fig. 16. Type 1505 used for checking magnetic heads for tape recorders.

this lies within the limits of the measuring range of the Bridge (0.2 mH to 2 H the transformer is well suited for the purpose.

For a reproduce head the data may be: V = 2 mV, L = 75 mH. Consequently: $n = \frac{3500}{2 \times 2} = 875$, and the corresponding impedance transformation: $L^1 = 75 \times 10^{-3} \times 875^2 = 57{,}500$ H. In this case the impedance transformation is the limiting factor, and the maximum transformer ratio is $n = \sqrt{\frac{10}{75 \times 10^{-3}}} = 11.5$. The Bridge voltage required would then be only $V_B = 2 \times 2 \times 11.5 = 46$ mV. The red mark on the 20 % scale will then indicate $20 \frac{V_{20}}{46} =$ approx. $20 \frac{150}{46} \sim 60$ %, where V_{20} is the normal Bridge voltage used for the 20 % range.

More exact measurements would in this case be obtained with the 1 kc/s Bridge (Type 1504) the maximum measurable inductance of which is 100 H. The Bridge voltage V_B would then be $V_B = 2 \times 2 \times 11.5 \times \sqrt{10} \sim 150$ mV, and the 20 % range could be used in the normal way.

Corrections Curves for Range Adjustment



Specification

Measuring Ranges of Test Components:

Resistance: 10 Ω—1 MΩ
Capacitance: 30 pF—1 μF
Inductance: o.2 mH—2 H

Measuring Ranges for Testing Components, Using Two External Standards:
Permits Direct Reading:

Resistance Range from 0—o.15 Ω to 0—350 kΩ
Capacitance Range from 0—1.5 pF to 0—o.35 μF
Inductance Range from 0—15 μH to 0—350 mH

Measuring Frequency: 10 kc/s.

Meter:
Large moving-coil instrument with removable scales. Illuminated scale with centre zero. Perfectly safeguarded against overload. Impedance deviation ranges: — 1.5 % to + 1.5 %, — 7 % to + 8 %, — 25 % to + 35 % and — 50 % to + 100 % and for phase angle deviations: (— 1.5 to + 1.5) $\times 10^{-2}$, (— 7 to + 7) $\times 10^{-2}$, (— 30 to + 30) $\times 10^{-2}$ and (— 80 to + 80) $\times 10^{-2}$ radians.

Accuracy of Impedance Measurements: Better than o.03 % for deviations close to zero. With zero phase angle difference between standard and unknown: Better than 3 % of indicated deviation at full scale deflection.

Max. Speed of Operation: 4ooo units per hour.

Stability: The zero reading is independent of the line voltage. Deflections from the zero point will change 3 % of indicated value for a 10 % variation of line voltage.

AC-Hum: The bridge is insensitive to hum voltages.

Impedance-Phase Angle Switch: A special micro switch permits rapid switching from impedance to phase angle measurements.

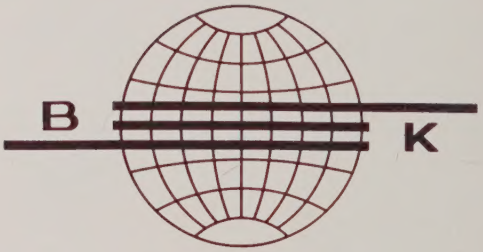
Tubes: 3 × 6AU6 (EF94), 6AQ5 (EL90), 6X4 (EZ90), OA2 (150C2).

European Model: Power Supply: 115 — 127 — 150 — 220 — 240 volts AC. 40—400 c/s, 40 watts.

American Model: Power Supply: 115 volts AC, 60 c/s, 40 watts.

Dimensions: 33 (height) × 28 (width) × 20.5 (depth excl. dials) cm.
13 (height) × 11 (width) × 8 (depth excl. dials) inch.

Weight: 10 kg (22 lbs.)



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